Low Cost Very Large Diamond Turned Metal Mirror

Contract No. NNX10CB49C (SBIR 08-2 S2.04-9926) (MSFC)

Mirror Technology SBIR/STTR Workshop

June 20th to 23rd, 2011

Greenbelt Marriott , Greenbelt, Md.

John M. Casstevens
Dallas Optical Systems, Inc.
972-564-1156

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OUTLINE

- **CONCEPT AND GOALS**
- **MIRROR MFG. PROCESS**
- **PROGRESS TO DATE**
- **SUMMARY**

Concept and Goals

--- Develop and demonstrate a process for producing a light weight, stiff mirror substrate by electroplating a NiP alloy over a plastic foam mandrel which will be removed with solvent after plating.

--- Demonstration of diamond turning as a method of producing a high quality optical surface on the electroplated NiP substrate by producing a 300 mm (12 inch) diameter flat test mirror and a 600mm (24 inch) flat mirror.

--- Optical inspection of the finished mirrors to evaluate mechanical stability and stiffness and the extent of mirror internal structure print through on the finished optical surface as a function of faceplate thickness.

--- Optical and dimensional inspection and characterization of the finished mirror for overall optical figure accuracy and surface smoothness achieved by diamond turning.

MIRROR MFG. PROCESS

Electroform NiP tubes with the required length and diameter and with one end closed and the other open.

Machine plastic foam to desired shape of substrate master. With press-fit holes for NiP tubes which go completely thru the foam master.

Install electroformed tubes in foam master so that the ends of the tubes are flush with the optical contour of the foam master.

Seal and coat plastic master with electrically conductive thin film to allow electroplating.

Electroplate the master and inserted tubes to completely encapsulate the assembly; joining the tubes to the front and back surfaces to form a stiff , continuous NiP structure.

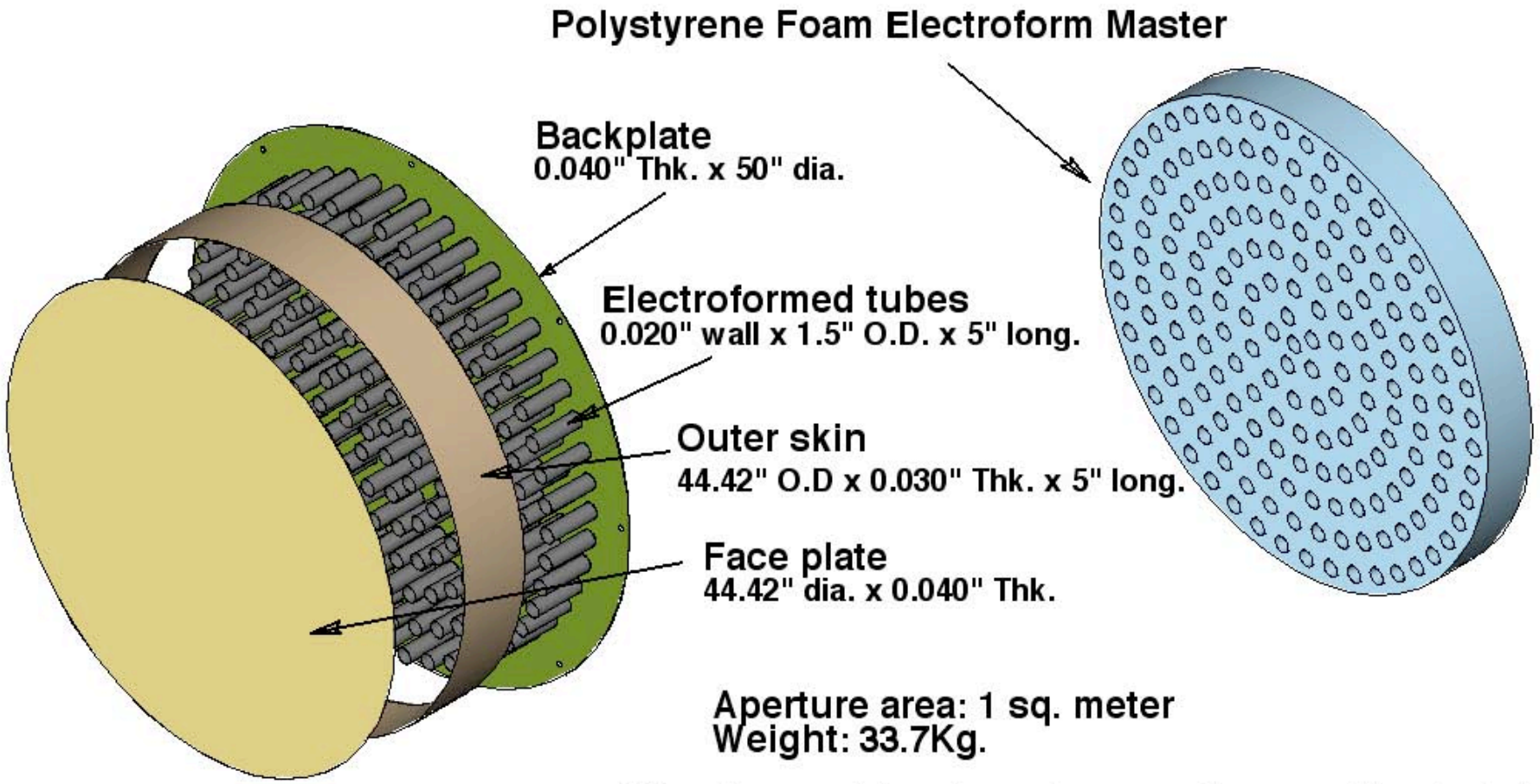
Drill access holes through the NiP skin to allow introduction of solvent.

Use solvent such as acetone to dissolve the plastic master and leave only a mirror substrate of electroplated NiP alloy.

Diamond turn the exterior of the NiP mirror substrate to produce the desired optical contour and mounting and reference surfaces.

Optical inspection of the finished mirror.

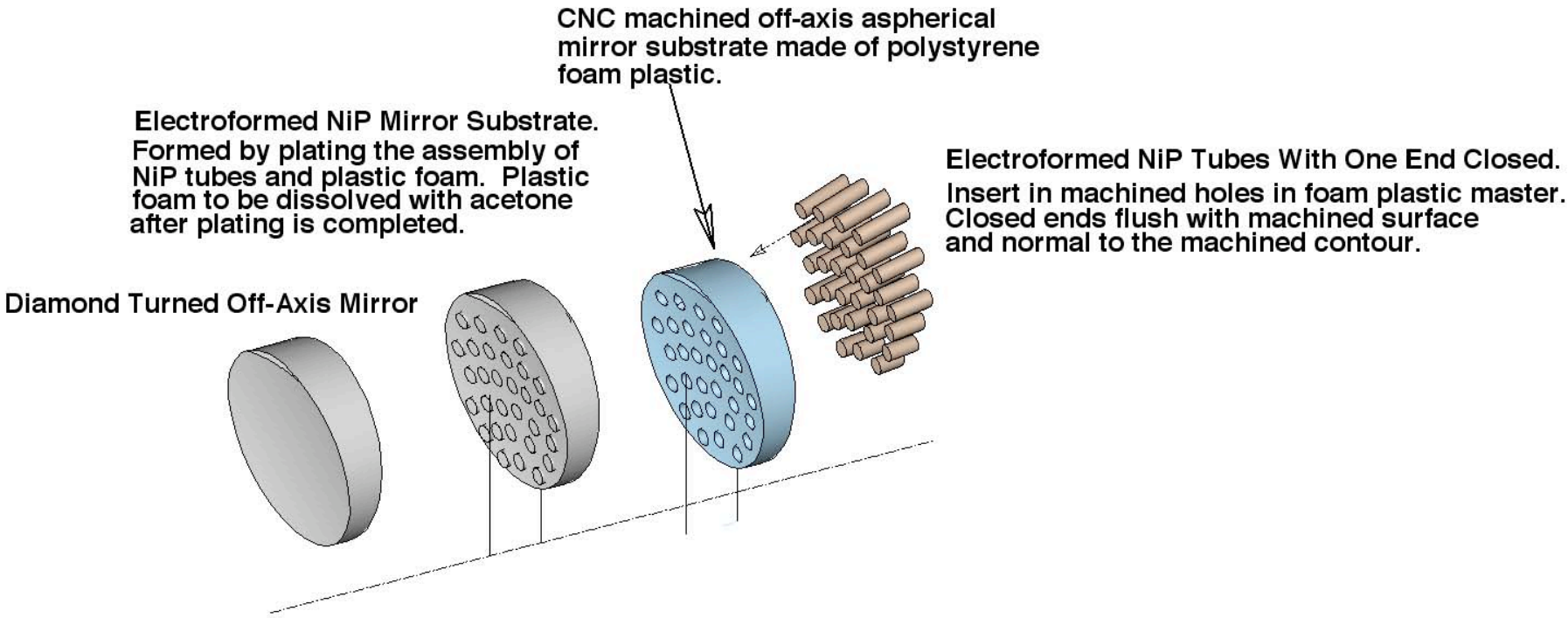
Weight of 1 Sq. Meter Mirror



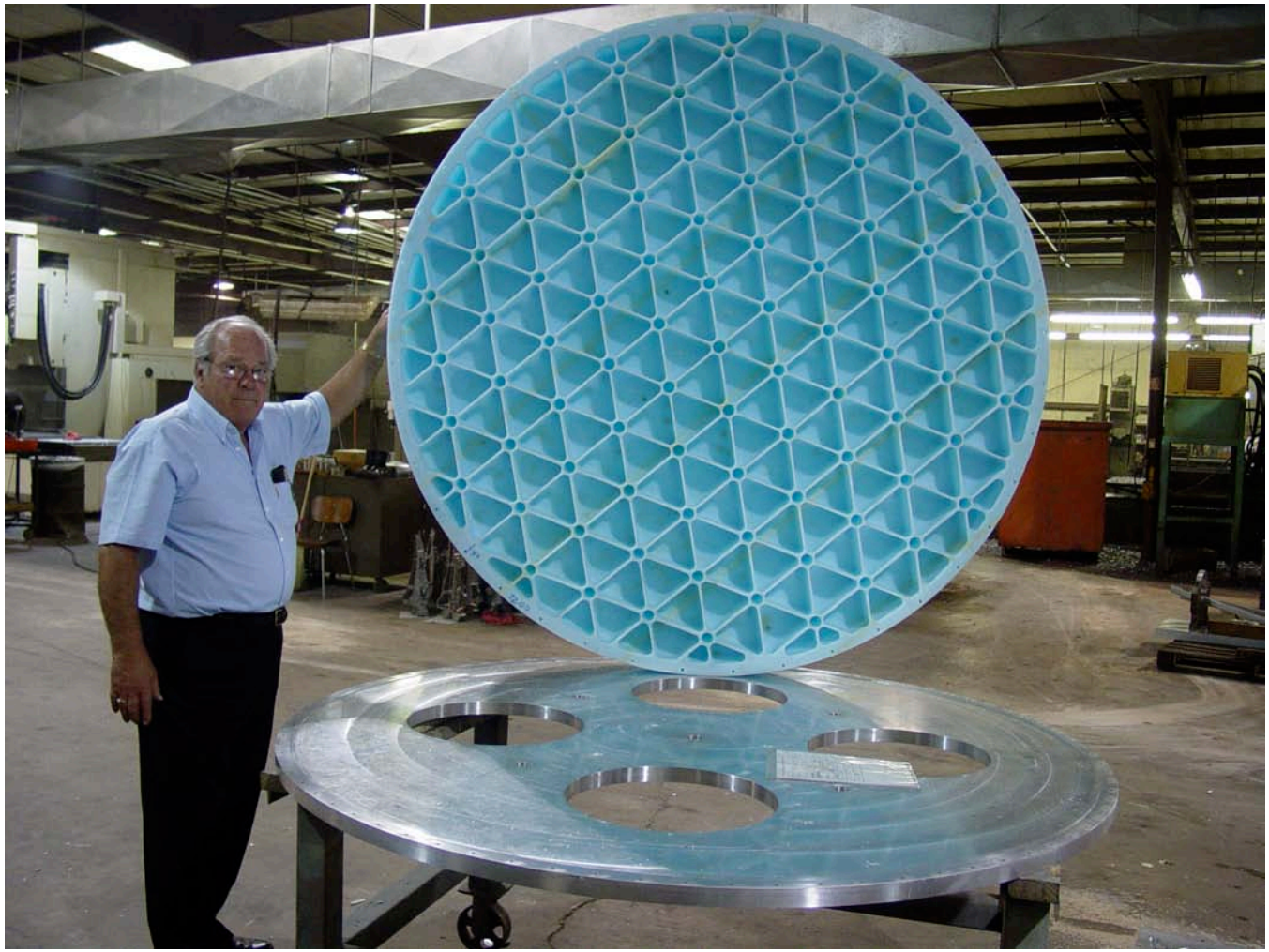
Aperture area: 1 sq. meter
Weight: 33.7Kg.

After diamond turning mirror surface and back plate.
Weight: 27 Kg.

Off-Axis Aspheric Mirror



1.8 Meter Diameter Foam Plastic Mirror Substrate



2.48 Meter Aluminum Mirror

Large Part Diamond Turning Experience

Technology

- A very important enabling process for plating high phosphorus nickel alloys using an electrolytic process has been developed at the University of Alabama at Huntsville and at Marshall Space Flight Center. This plating process has been demonstrated to be capable of producing very low stress deposits of very high quality that allow excellent surfaces to be diamond turned on the NiP deposit. The electrolytic NiP plating process is not limited in plating thickness. Thick wall, structurally robust mirror substrates can be built up with this electroplating process.

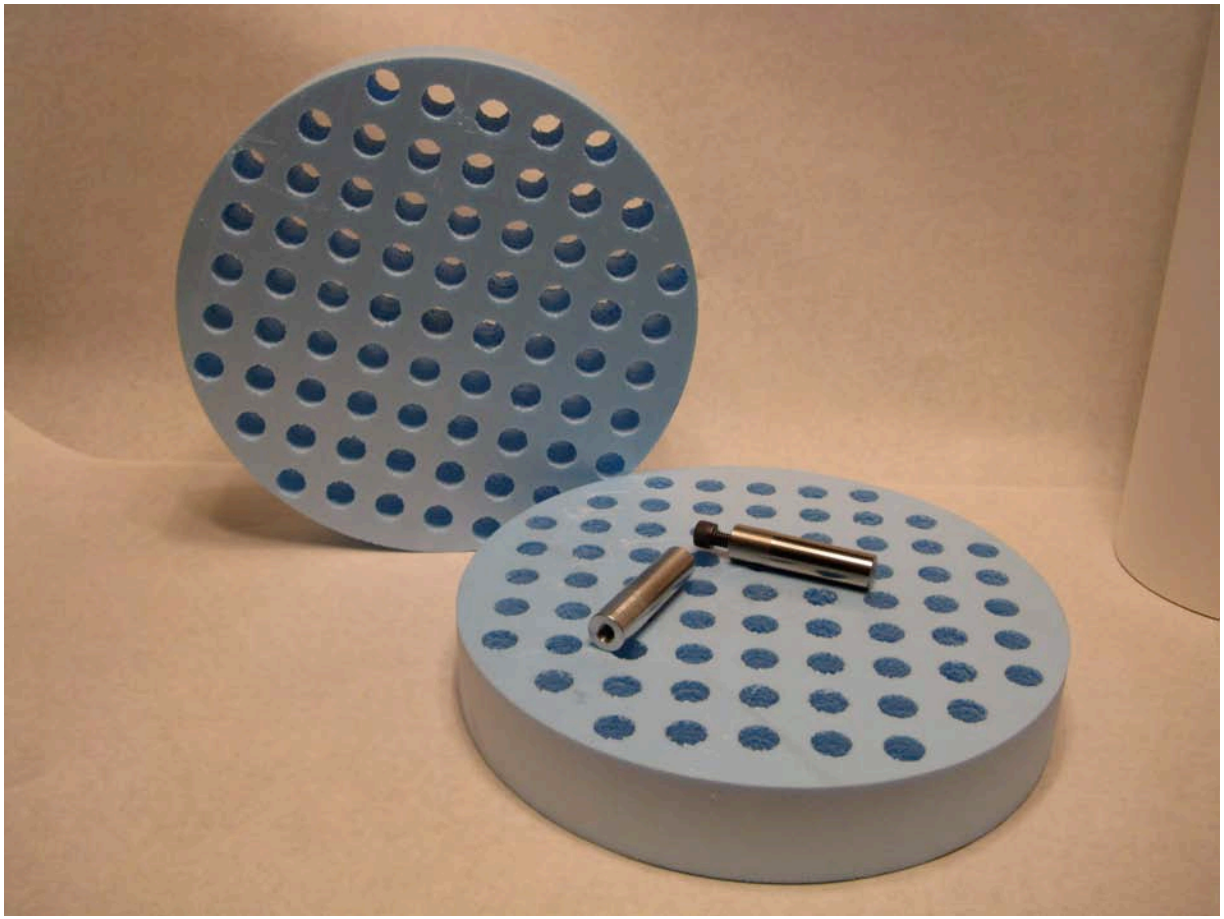
Electrodeposited Nickel Phosphorus

Comparison of Nickel Phosphorus Deposition to Other Processes

Parameter	Nickel	Electroless Nickel	NiP & NiCoP (Electrolytic)
Plating Temp °C	38 – 50	82 – 90	40 – 50
Control Method	Soluble Anode	Chemical Replenish	Soluble Anode
Yield (0.2%) (MPa)	500	See UTS	See UTS
MicroYield (MPa)	70	500 +	830 +
UTS Max (MPa)	800	850	1800 – 2150
Specific Gravity	8.9	7.8 – 8.0	7.8 – 8.0
Stress Control (Real Time)	Yes	No	Yes
Hardness (Rockwell C)	22 – 24	48 – 52	48 – 52
Diamond Machining	No	Yes	Yes
Thick Deposits	Yes	No	Yes

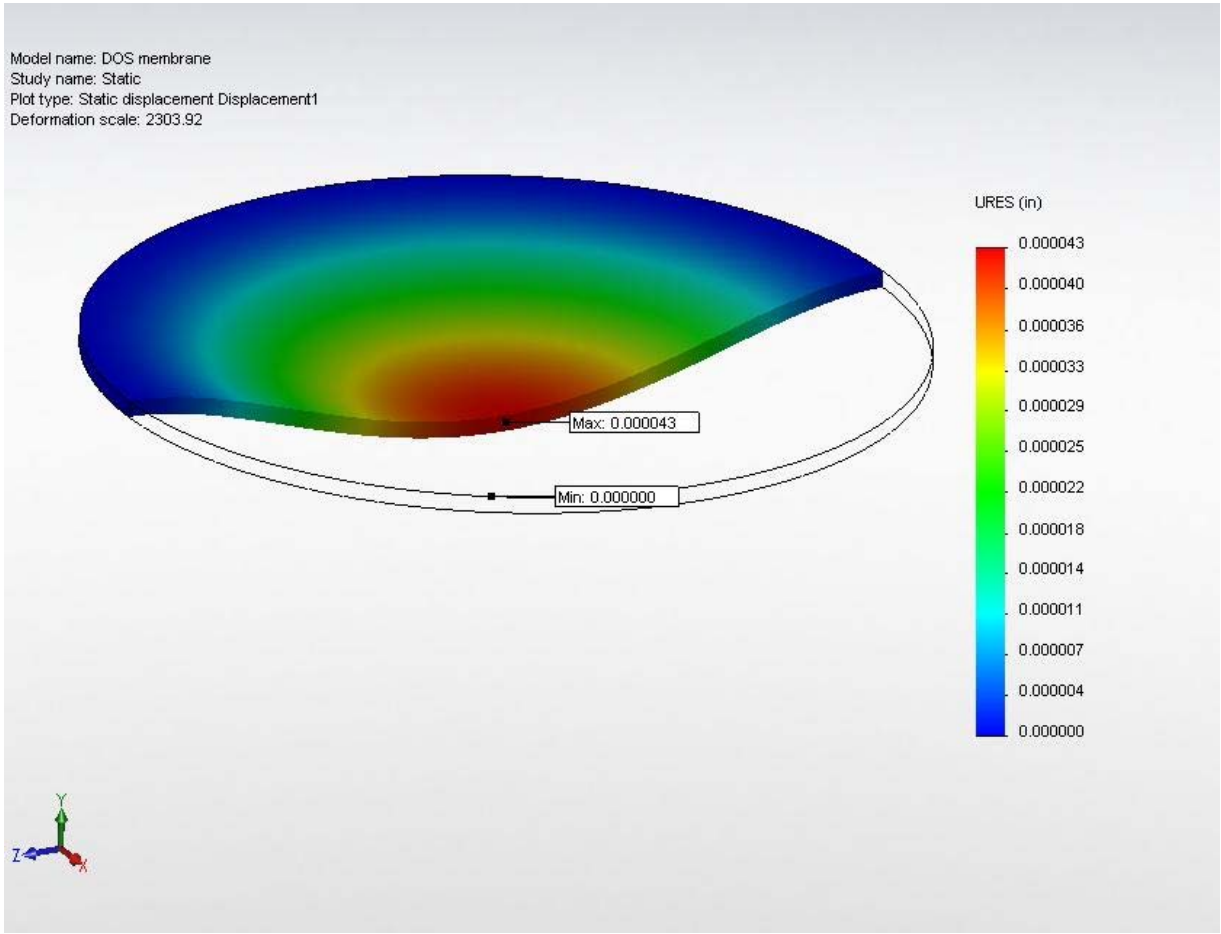
Electroforming Technology Developed by UAH and MSFC for X-Ray Telescope Fabrication

0.3 Meter PLASTIC FOAM MIRROR FORM

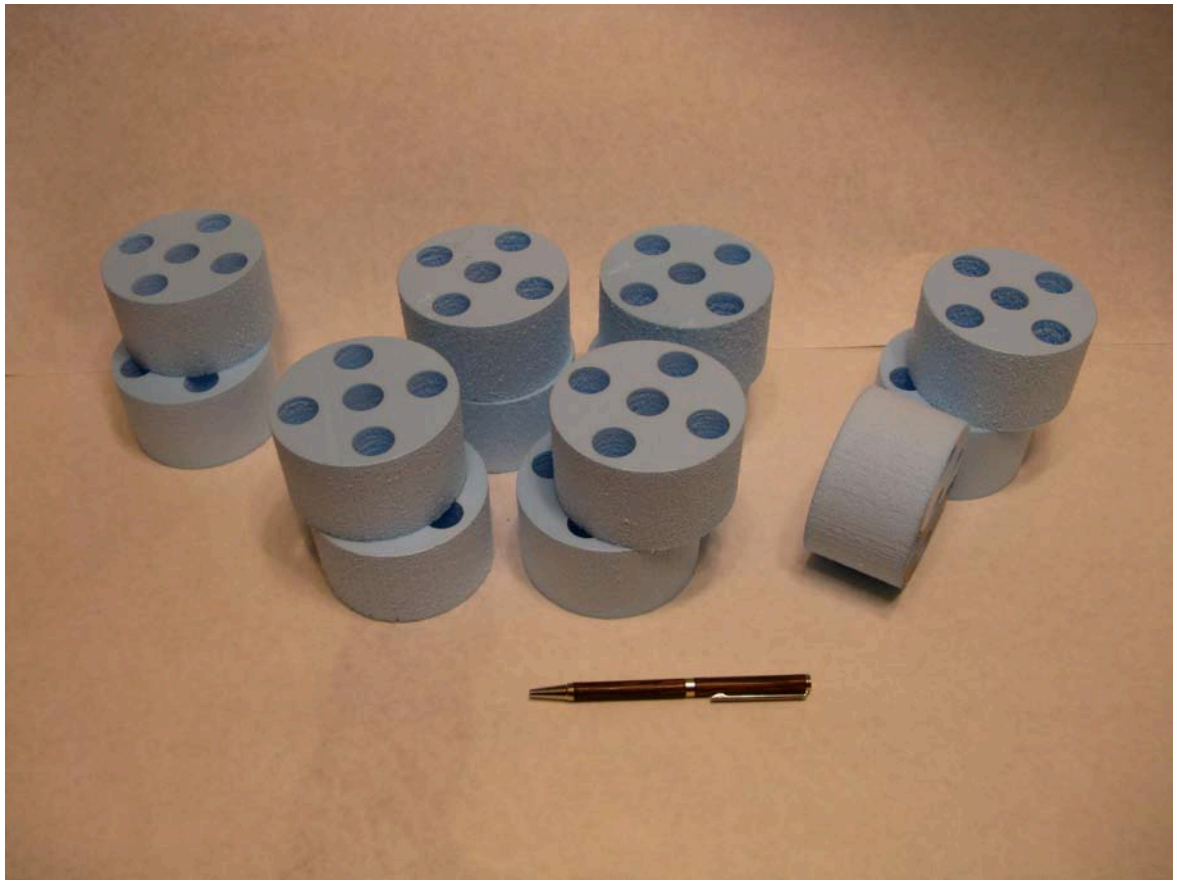


MIRROR DESIGN

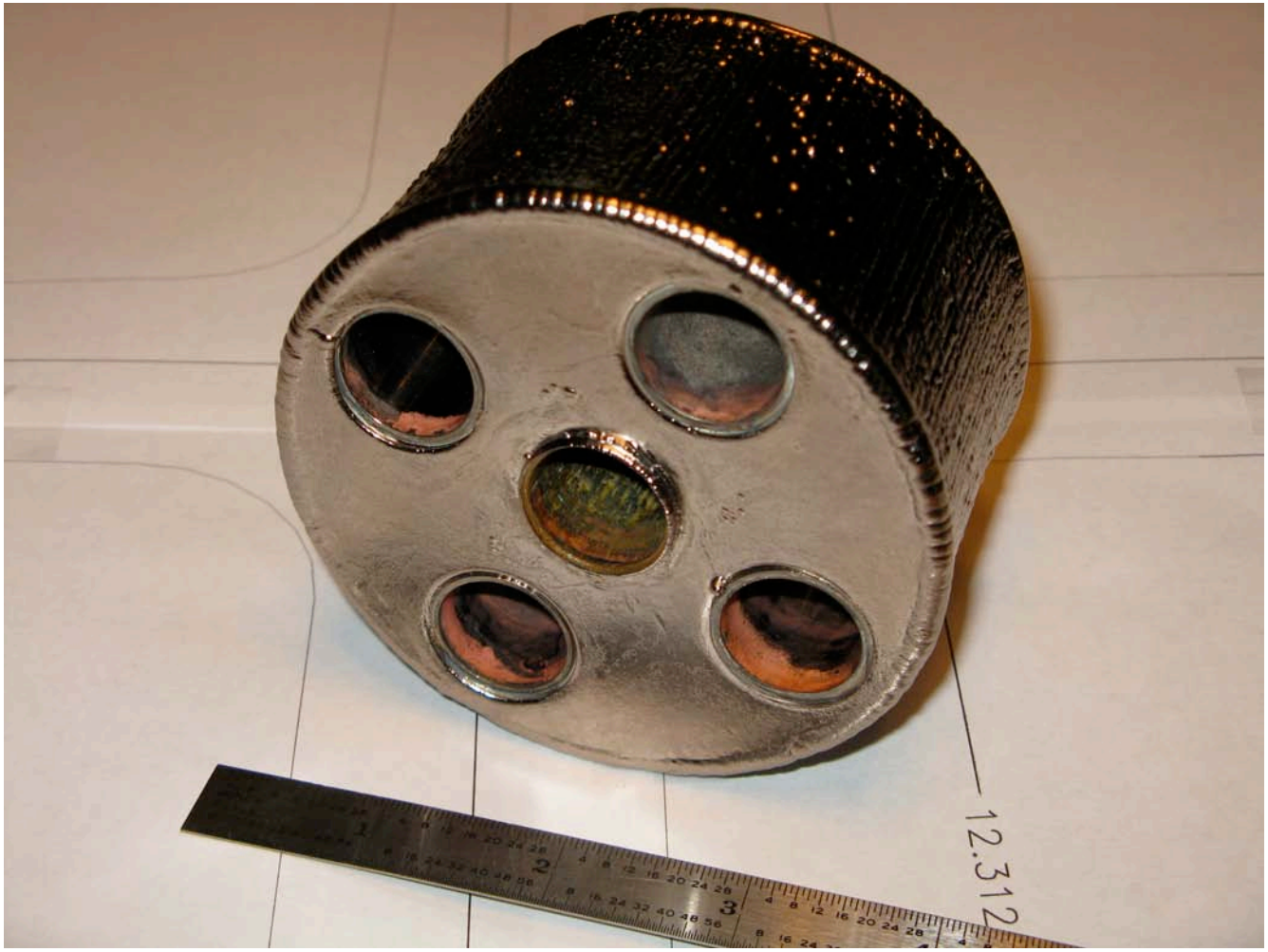
Plating thicknesses and diameter and spacing of tubes optimized for best performance.



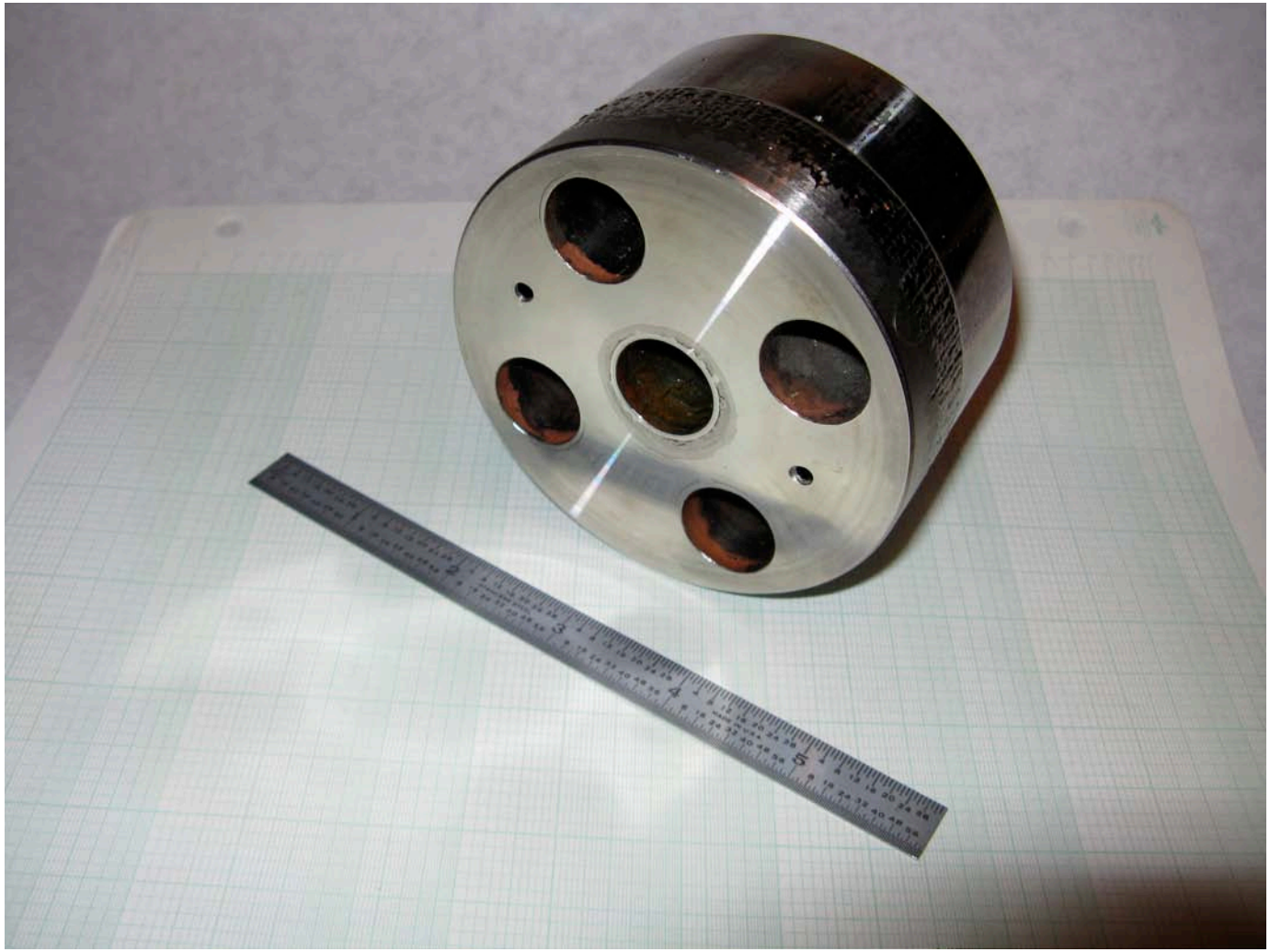
89mm DIAMETER FOAM MASTER FORMS



NiP Plated 89mm Mirror Substrate Assembly



Precision Machined Back of Plated Mirror Assembly



Diamond Turned and Polished NiP Mirror

SBIR GOAL IS A *LOW COST PROCESS* FOR 3 MT. MIRRORS

CLOSED END ELECTROFORMS ARE NOT PRACTICAL

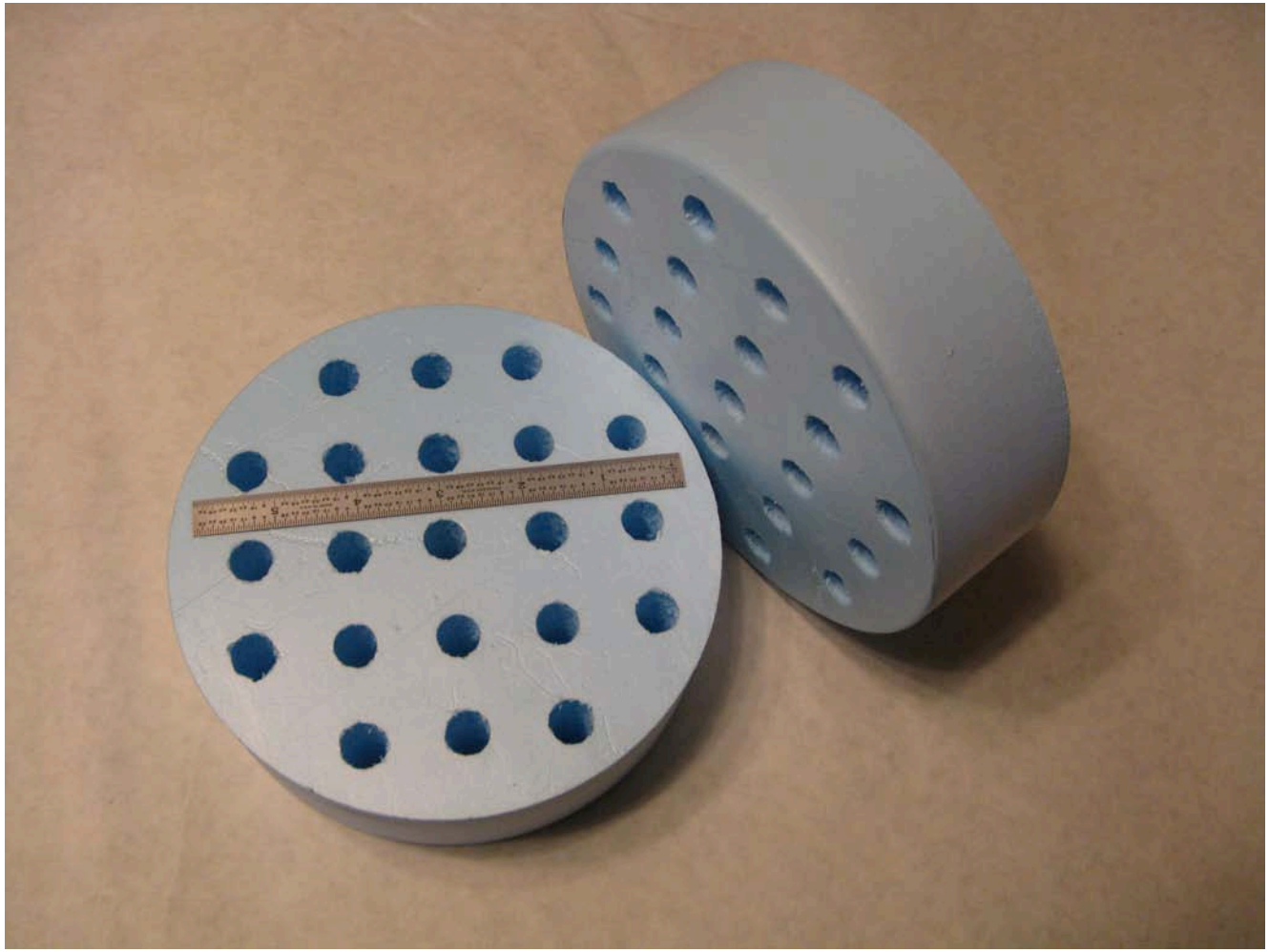
- Large mirrors require production of thousands of tubes.
- Curved mirrors require tubes of different lengths.
- Large production of tubes of many lengths not cost effective.

PRODUCTION FRIENDLY METHOD FOR ELECTROFORMED TUBES

- Electroform long tubes and cut to required lengths.
- Open end tubes allow holes in foam to be parallel to optical axis.
- Inserted electroformed tube assemblies can be matched to contour.
- Removal of mandrels from electroformed mirrors must be reliable.
- Chose acrylic rod mandrel removed by differential shrinkage.

SULFAMATE NICKEL PLATED ACRYLIC PLASTIC RODS CUT TO MATCH STYRENE FOAM

175 mm Diameter Polystyrene Foam Mandrels

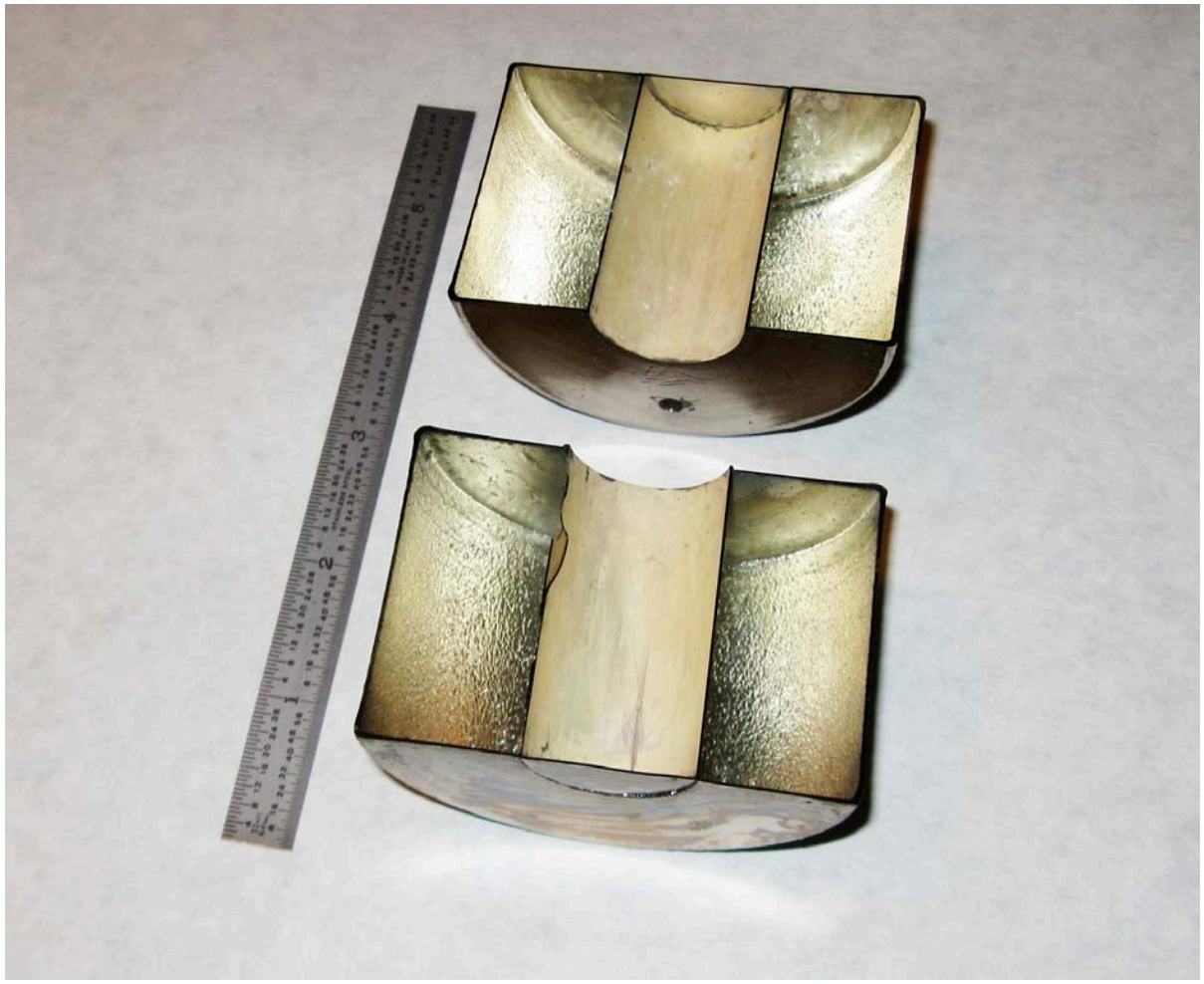


ISSUES FOR ELECTROFORMING TUBES ON RODS

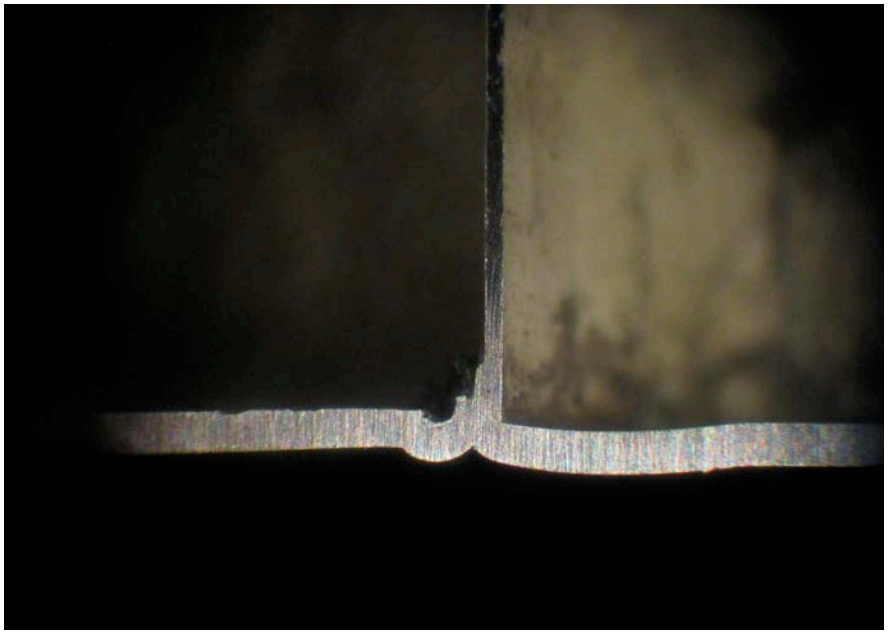
- **Cutting composite of hard nickel on soft rod is difficult.**
- **Polymer rod must be smooth, round and constant diameter.**
- **Polymer must allow reliable mandrel removal from mirror substrate.**
- **Nickel Phosphorus is a hard, strong and brittle material.**
- **Removal of mandrels must be a low force process.**
- **Electrically conductive coatings on polymer must be reliable.**

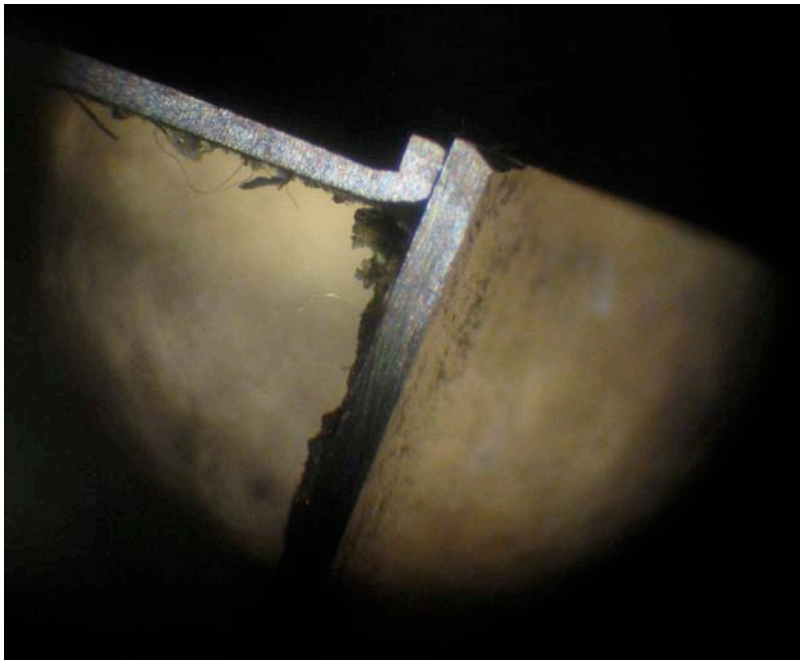
Acrylic Rod Removed From Test Mirror By Differential Shrinkage

Test Mirror Cut in Half for Evaluation of Joint Quality



Micrographs of Unreliable Tube to Mirror Face Joint





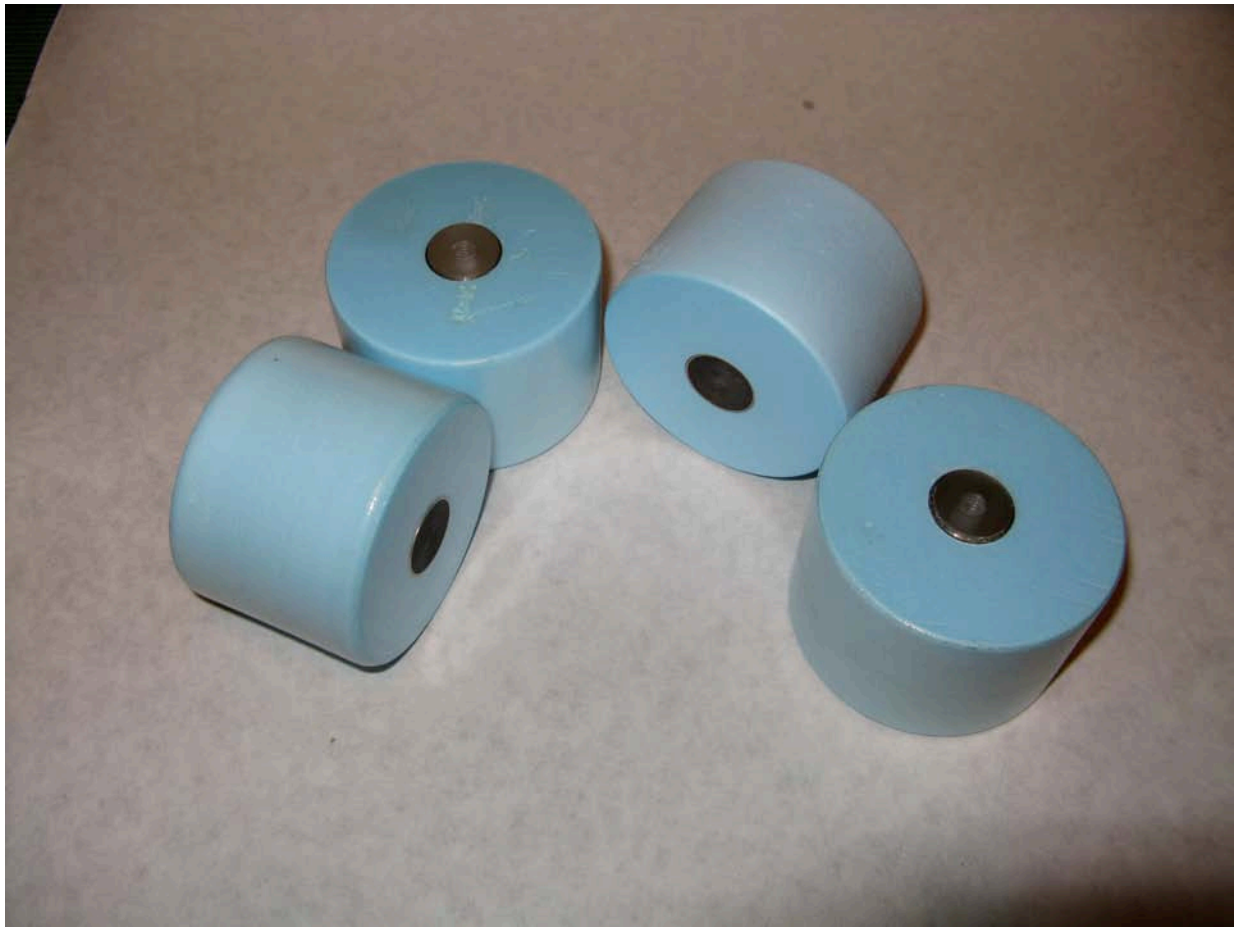
FRONT FACE

BACK FACE

HIGH QUALITY JOINT STRENGTH AT TUBE ENDS

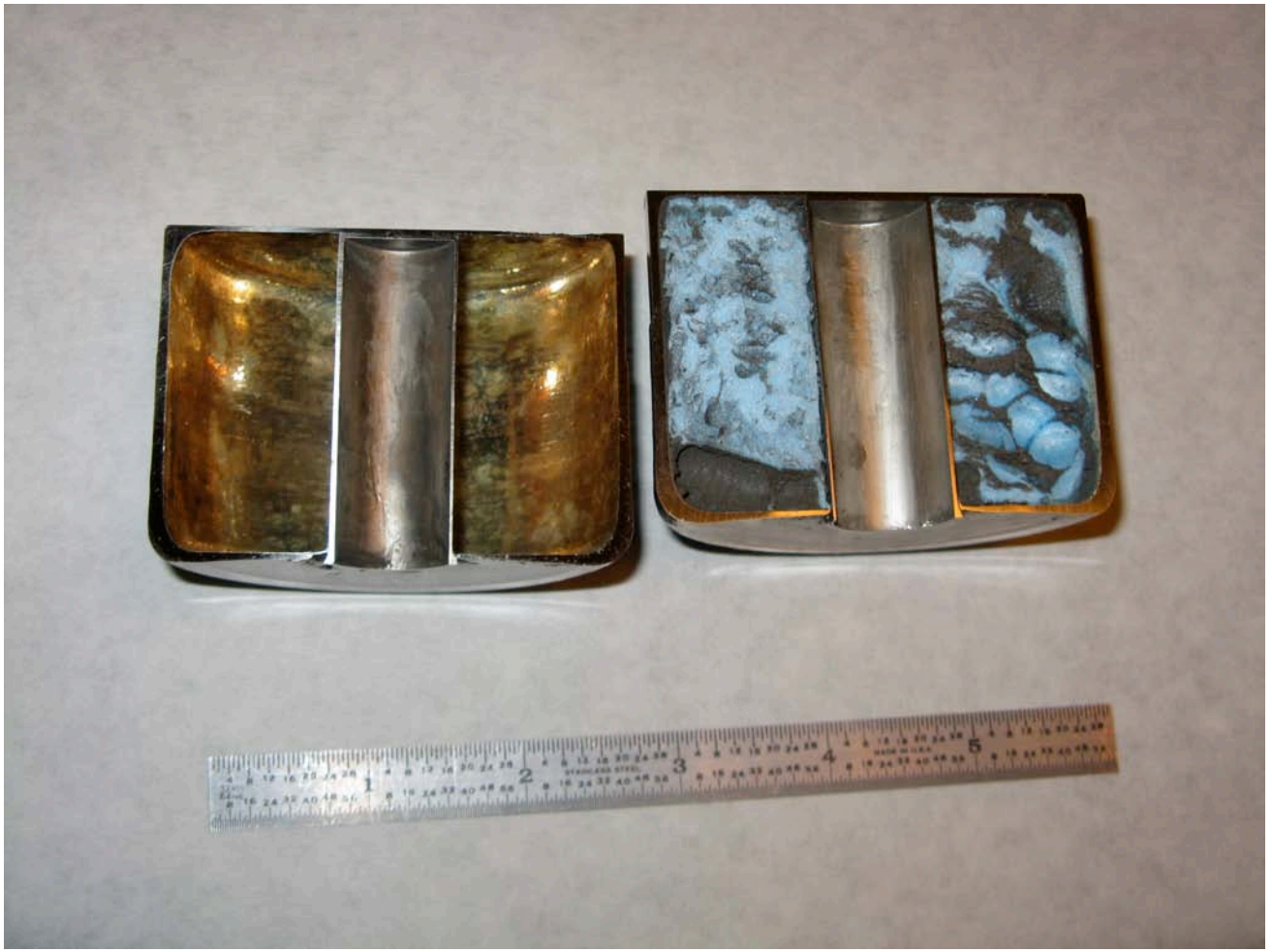
- Continued development of plating methods on polymers.
- Rough DT of NiP substrate to expose ends of mandrels.
- Electroformed tubes must be machineable with diamond.
- Ductile sulfamate nickel is not compatible with diamond tools.
- Only one material means low thermal distortion.
- More testing to develop methods of addressing these problems.
- Use one tube in 80mm diameter foam mandrels for tests.

Test Mirror Assemblies With Nickel Plated Acrylic Rod



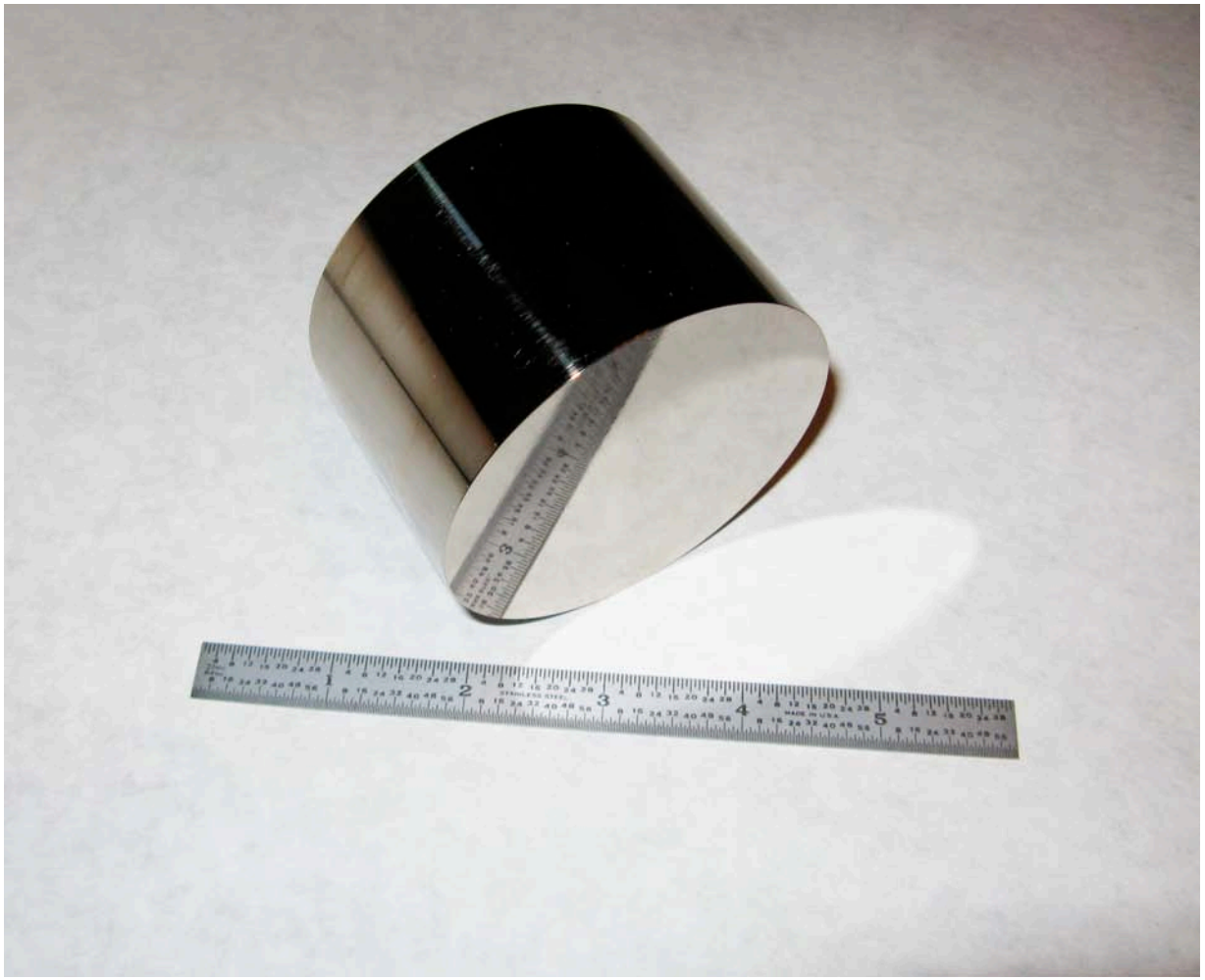
Four Test Mirror Substrates After NiP Plating

Test Mirror Cut in Half for Evaluation of Joint Quality



High Quality NiP Plated Test Mirror Substrate

Diamond Turned and Polished NiP Test Mirror



MANDREL DEVELOPMENT

- Low cost composite mandrel material for electroplating of NiP.
- Easier faster cutting of plated rods to required length.
- Castable mandrel material is recycleable low cost and low waste.
- Composite tube mandrel allows mandrel removal by differential thermal expanision, melting and dissolution.
- New mandrel for electroplating meets SBIR goal of very low cost of large mirror substrates.
- Currently using composite tube mandrel material for mirror tests.

NiP Plated Composite Tube Assemblies

SUMMARY

- **Low Cost Mirror *SUBSTRATE* by Electroplating of NiP.**
- **Diamond Turning & Post Polish of NiP Electroformed Substrate.**
- **Low Cost Very Flexible Manf. Process for Large Mirrors.**
- **Low (10-30 Kg/Sq. Meter) Areal Density, Very stiff metal mirror.**
- **Only one material means low thermal distortion.**
- **Currently using composite tube mandrel which allows mandrel removal by thermal expansion, melting and dissolution.**